Study of RPC gas mixtures for the ARGO-YBJ experiment

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Abstract

The ARGO-YBJ experiment consists of a RPC carpet to be operated at the Yangbajing laboratory (Tibet, P.R. China), 4300 m a.s.l., and devoted to the detection of showers initiated by photon primaries in the energy range 100 GeV - 20 TeV. The measurement technique, namely the timing on the shower front with a few tens of particles, requires RPC operation with 1 ns time resolution, low strip multiplicity, high efficiency and low single counting rate. We have tested RPCs with many gas mixtures, at sea level, in order to optimize these parameters. The results of this study are reported.

1 Introduction

The ARGO-YBJ experiment [1] is under way over the next few years at the Yangbajing High Altitude Cosmic Ray Laboratory (4300 m a.s.l., 606 g/cm^2), 90 km North to Lhasa (Tibet, P.R. China). The aim of the ARGO-YBJ experiment is the study of fundamental issues in Cosmic Ray and Astroparticle Physics including γ-ray astronomy, GRBs physics at 100 GeV threshold energy and the measurement of the $\overline{p}/p$ at TeV energies. The apparatus consists of a full coverage detector of dimension $71 \times 74\ m^2$ realized with a single layer of Resistive Plate Counters (RPCs). A guard ring partially (about 50 %) instrumented with RPCs, surrounds the central detector, up to $100 \times 100\ m^2$; it improves the apparatus performance by enlarging the fiducial area for the detection of showers with the core outside the full coverage carpet.

A lead converter 0.5 cm thick will cover uniformly the RPC plane in order to increase the number of charged particles by conversion of shower photons and to reduce the time spread of the shower particles. The measurement technique, namely the timing on the shower front with a few tens of particles, requires RPC operation with 1 ns time resolution, low strip multiplicity for good energy estimation at low energies, high efficiency and low single counting rate to trigger efficiently at low multiplicity.

Keeping in mind all these needs and the low operating pressure (about 600 mbar) at Yangbajing we started to investigate different gas mixtures, at sea level, in order to optimize the detector performance. In fact previous studies have shown that

the performance of the detector may be heavily affected by the reduced pressure [2]. Three gas components were used: Argon, iso-Butane C4H10 and TetraFluoroEthane C2H2F4 that will be indicated in the following as Ar, i-But and TFE respectively.

The set-up used for this study consists of a small telescope of 4 RPCs 50×50 cm^2 area with 16 pick-up strips 3 cm wide connected to the front-end electronics board . The front-end circuit contains 16 discriminators, with about 70 mV voltage threshold, and provides a FAST-OR signal with the same input-to-output delay (10 ns) for all the channels. The 4 RPCs were overlapped one on the other, 3 out of them were used to define a cosmic ray beam by means of a triple coincidence of their FAST-OR signals, the fourth one was used as test RPC. The three RPCs providing the trigger were operated with a gas mixture of 60% Ar, 37% i-But and 3% TFE. At any trigger occurrence the time provided by the test RPC was read by means of a LECROY TDC of 0.25 ns time bin, operated in common START mode; the number of fired strips was read by means of a CAEN module C187. The single counting rate was read by a CAEN scaler C243.

2 RPC performance

The RPCs were operated in streamer mode, as foreseen for the experiment, at the ARGO laboratory of the Physics Department of the Naples University.

Many gas mixtures have been tested, including mixtures with a high percentage of Ar (40% - 60%) which represent a reference point for the performance of the detector. The results are shown in Fig. 1 where in the first column a) are reported the three mixture with Ar kept at 60%; the numbers associated to each line like 60/30/10 refer respectively to Ar/i-But/TFE. It can be seen that changing the relative percentage of the two quenching components, i-But and TFE, does not result in any strong or evident difference of the detector performance. In fact the operating voltage does not chance substantially, neither the efficiency; the time resolution stabilizes around 1 ns and the strip multiplicity ranges in 1.1 - 1.3 depending on the applied voltage. This is confirmed by the set of measurements done with Ar kept at 40% (column b). Only the mixture 40/50/10 shows some difference, but it is likely that there was some uncontrolled change or problem during the data taking.

In order to check gas mixtures with i-But content around and below the flammability threshold (10%) we have performed measurements with mixtures where the i-But fraction was kept at 10% in one set and 2% in another set. The results are reported in column a) and b) of Fig. 2. Both samples of measurements show that the Ar percentage plays an important role in defining the operating voltage (about 800 V above the knee-voltage V_{knee}) and influences the strip multiplicity. The mean value of the strip multiplicity remains anyway below 1.3; also the single rate changes according to the Ar percentage and this can be understood as we work at fixed discrimination threshold. Efficiency and time resolution are not affected. This means that i-But, traditionally used to "quench" the discharge by asbsorption of ultraviolet photons, can be substituted almost completely by TFE which is electronegative and

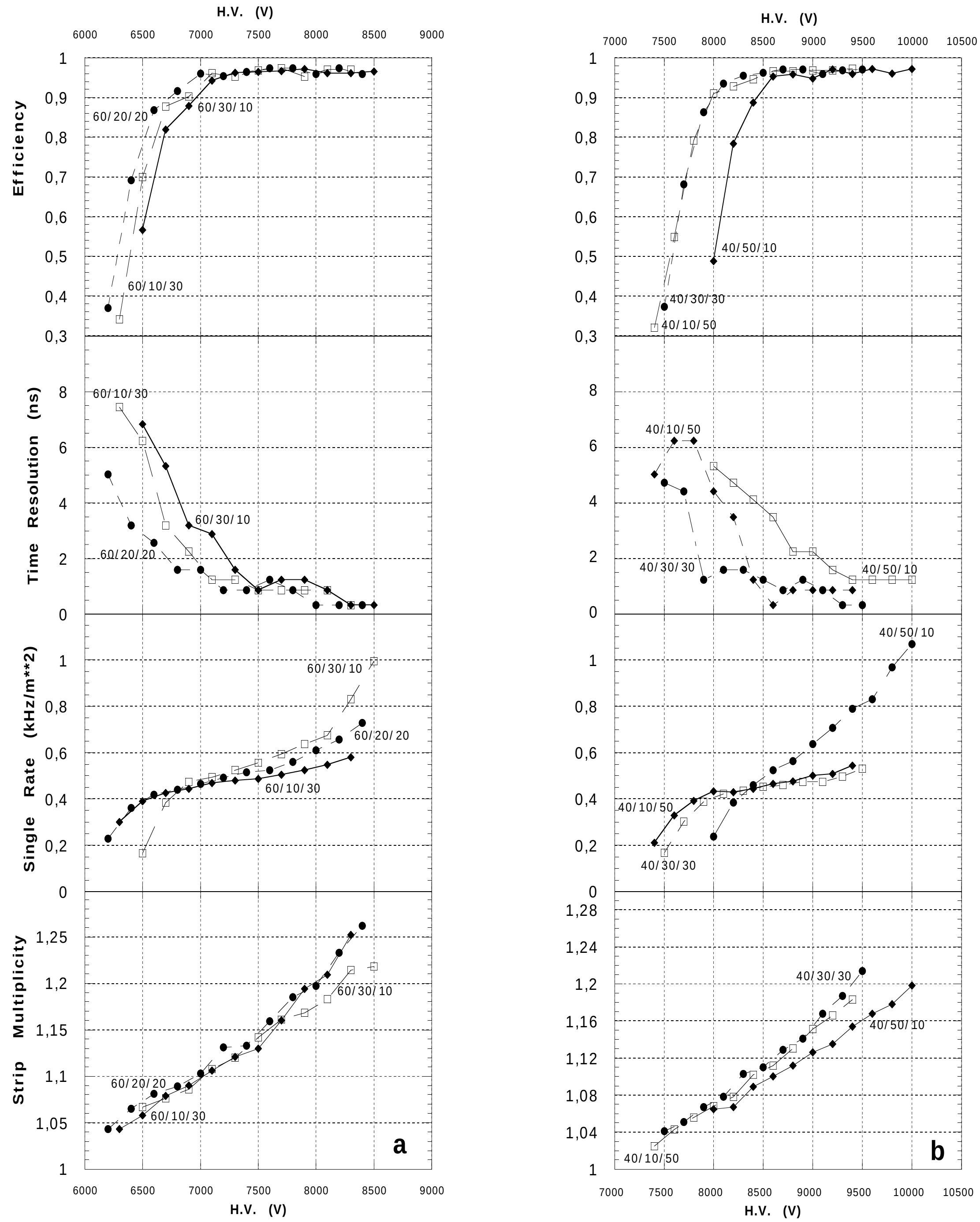

Fig. 1. Efficiency, time resolution, single rate and mean strip multiplicity for gas mixtures with a) 60% of Ar; b) 40% of Ar.

captures electrons of the plasma.

A solution to the problem of low pressure is increasing the density of the gas mixture. An increase of TFE concentration at expenses of the Ar concentration should therefore increase the primary ionization thus compensating for the 40% reduction caused

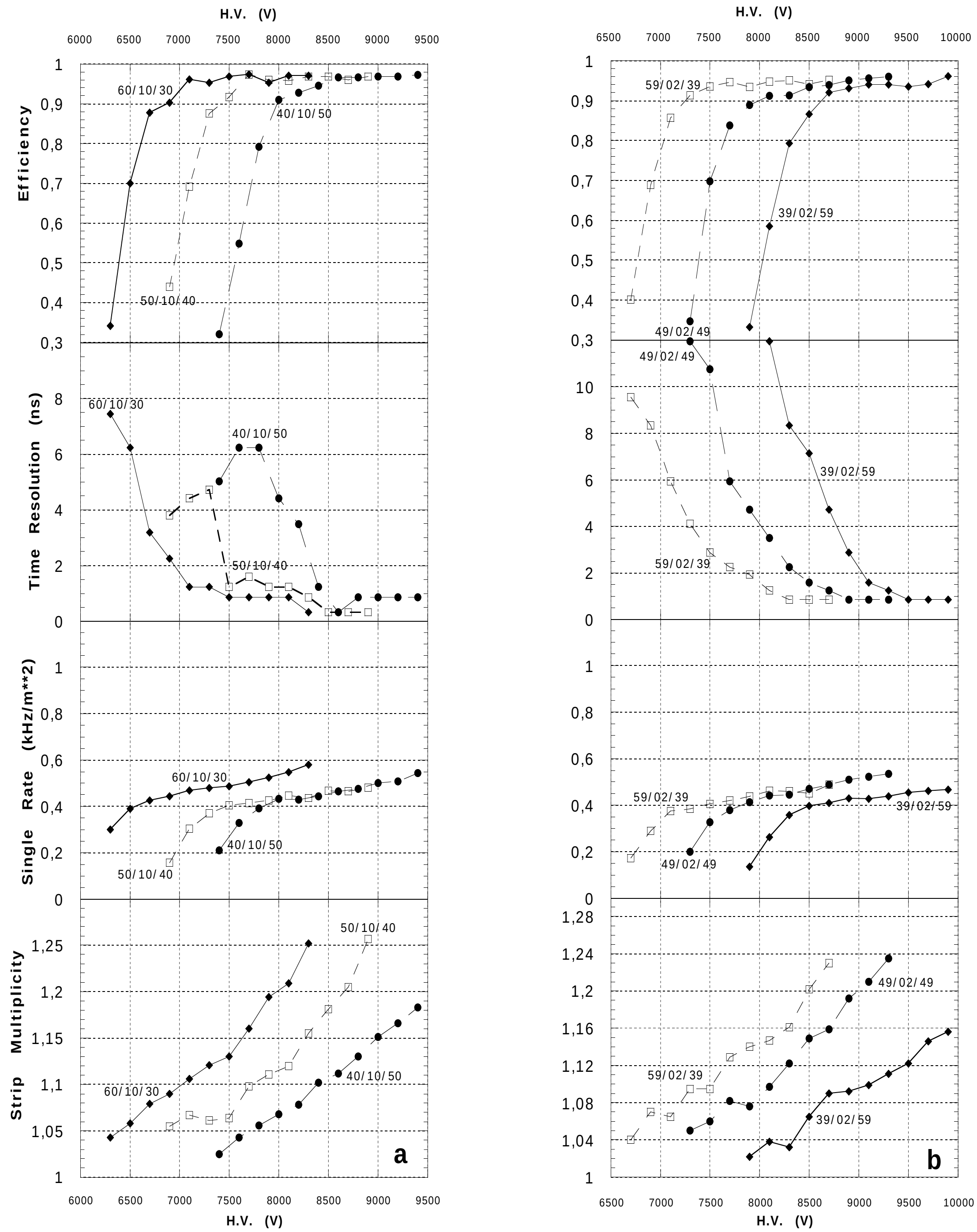

Fig. 2. Efficiency, time resolution, single rate and mean strip multiplicity for gas mixtures with a) 10% of i-But; b) 2% of i-But.

by the lower gas target pressure (600 $mbar$) and reduces the afterpulse probability. We have tested two mixtures with high content of TFE, namely Ar/i-But/TFE : 15/10/75 and 15/5/80; the second one is a non flammable mixture. The experimental results (Fig. 3) do not exhibit evident differences between them. The reduction of the Argon concentration in favour of TFE results in a clear increase of the oper-

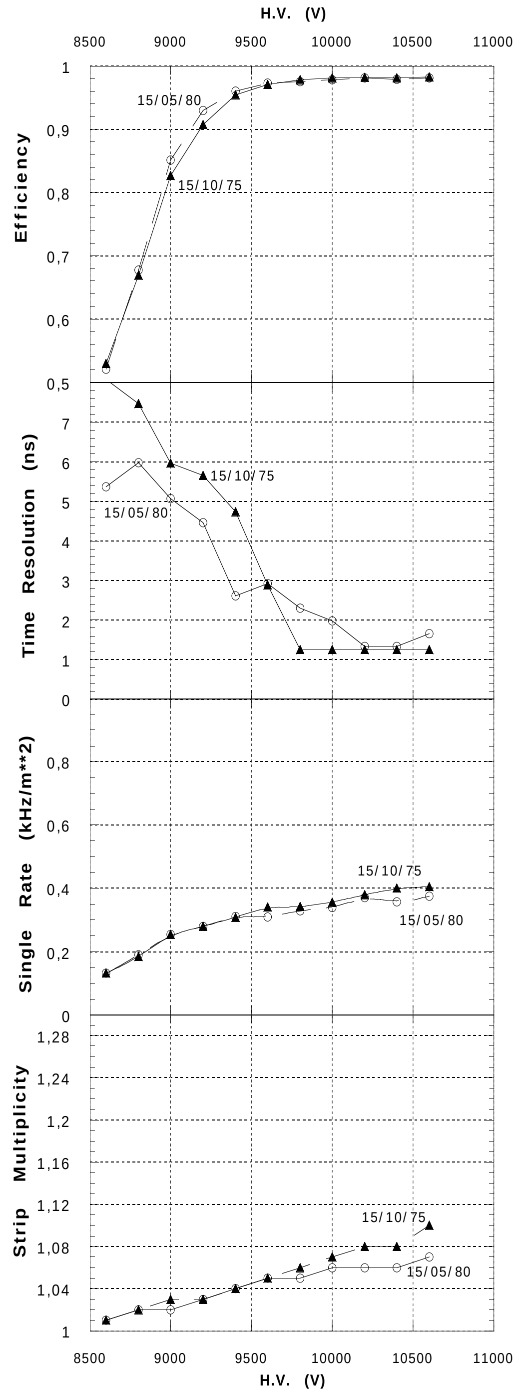

Fig. 3. Efficiency, time resolution, single rate and mean strip multiplicity for the gas mixtures Ar/i-But/TFE = 15/10/75 and Ar/i-But/TFE = 15/5/80.

ating voltage as expected from the large quenching action of TFE. The efficiency, 98%, is comparable to the values obtained with the mixtures having low percentage of TFE; might even be higher but this, given the experimental fluctuations, cannot be stated with certainty. Moreover, the time resolution doesn't show any worsening,

the single rate keeps below 400 Hz/m^2 and also the strip multiplicity stays below 1.1. The mixture 15/10/75 has been already used successfully at Yangbajing in the ARGO test [3] [4].

3 Conclusions

We have studied the performance of RPCs with gas mixtures made of Ar, i-But and TFE. We checked mixtures with a high percentage of Ar, mixtures with low content of i-But, and finally mixtures with low and high percentage of TFE. For all of them, apart from those with a high percentage of TFE, we can summarize as follows: 1) the efficiency is $95 \div 97\%$; 2) the voltage where the efficiency plateau starts and the working voltage (tipically V_{knee} + 800 V) depends strongly on the Ar fraction, showing an increase of about 500 V per every 10% Ar reduction); 3) the single rate shows a plateau in the frequency range 400 Hz/m^2 - 600 Hz/m^2; 4) the time resolution at working voltage is tipically $1.0 \div 1.3$ ns; 5) the mean value of the strip multiplicity at the working voltage is $1.15 \div 1.25$ depending on the Ar percentage.

The mixtures with higher TFE content result in sligthly better performance, giving 98% efficiency, lower strip multiplicity and single rate. We couldn't find any parameter able to discriminate the different mixtures. Preliminary measurements show that in mixtures with higher TFE fraction a smaller charge per track is developed. Tests are going on to investigate the analog read-out of the detector operated in streamer mode.

References

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